Performance analysis of ring current modeling

During a storm, the ring current becomes enhanced. The enhanced ring current perturbs the Earth's magnetic field in the opposite direction of the Earth's dipole field. This disturbance can be seen in a decrease in the Dst index measured by magnetometers on the Earth's surface. After the storm, the Dst index recovers to prestorm levels. This is due to losses in the ring current. Sometimes this recovery in the Dst index can happen on a rapid time scale (within hours). A study was done to determine if the Fok Ring Current Model could replicate the rapid recovery in the Dst index after a storm. An event was chosen that had a rapid recovery. The simulation was started two days before the storm and continued for three days after the storm period for a total period of five days. The test was to check whether the inclusion of pitch angle diffusion would produce the energy losses in the Fok Ring Current Model that would signify a rapid recovery of Dst.

The event was run using the BATSRUS MHD model. The Fok Ring Current Model takes the magnetic and electric field from the MHD model as inputs. The Fok Ring Current Model also uses the density and temperature from the MHD model to compute an outer boundary condition. The Fok Ring Current Model was run with and without pitch angle diffusion to determine what mechanism would produce sufficient losses in the ring current to account for the rapid recovery of the Dst index for this storm. In particular, we were looking for the energy loss mechanism in the ring current that would contribute to the increase in the Dst index.

Dst data was downloaded from the WDC-C2 KYOTO Dst index service. We compared the Dst data to the total energy in the ring current from the simulation results. The Dst index is related to the total energy in the ring current by the Dessler-Parker-Sckopke relation. In this comparison, we compared the negative of the total energy of the ring current to the Dst index for two cases. In this case, we were trying to determine the energy loss mechanism that would allow for the rapid recovery of the Dst index. In addition we used solar wind data and the Dst index to compute the Dst* index. Dst measures other currents besides the ring current. One current system included in the Dst index is the magnetopause currents. The Dst* index is a correction to the Dst index that is used to correct for the magnetopause currents. The Dst* index should be better measure of the ring current than Dst. We compared the ring current energy to both Dst and Dst*.

In the case without pitch angle diffusion, the Dst index recovered much faster than the total energy in the ring current. In this case, the two major energy loss mechanisms for the ring current were flow out losses through the magnetosphere and charge exchange. For this storm neither of these mechanisms accounted for a rapid recovery. The case was also done with a constant pitch angle diffusion coefficient of $1x10^{-3}$ s^{-1}. This value for the pitch angle diffusion coefficient is an above average value for the diffusion coefficient. This value would be an average peak value for the pitch angle diffusion coefficient. For a significant part of the modeling domain, this value for the pitch angle diffusion coefficient would be too high. In this case the simulation had a more rapid recovery than was seen in the Dst index. The major loss mechanism in this case was the diffusion term.

For this event, the results indicate that pitch angle diffusion must be included to account for the rapid recovery of the Dst index. Since the constant pitch angle diffusion case gives a recovery that is too rapid, a more sophisticated calculation of pitch angle diffusion coefficients is required to more accurately model the rapid recovery of the storm.

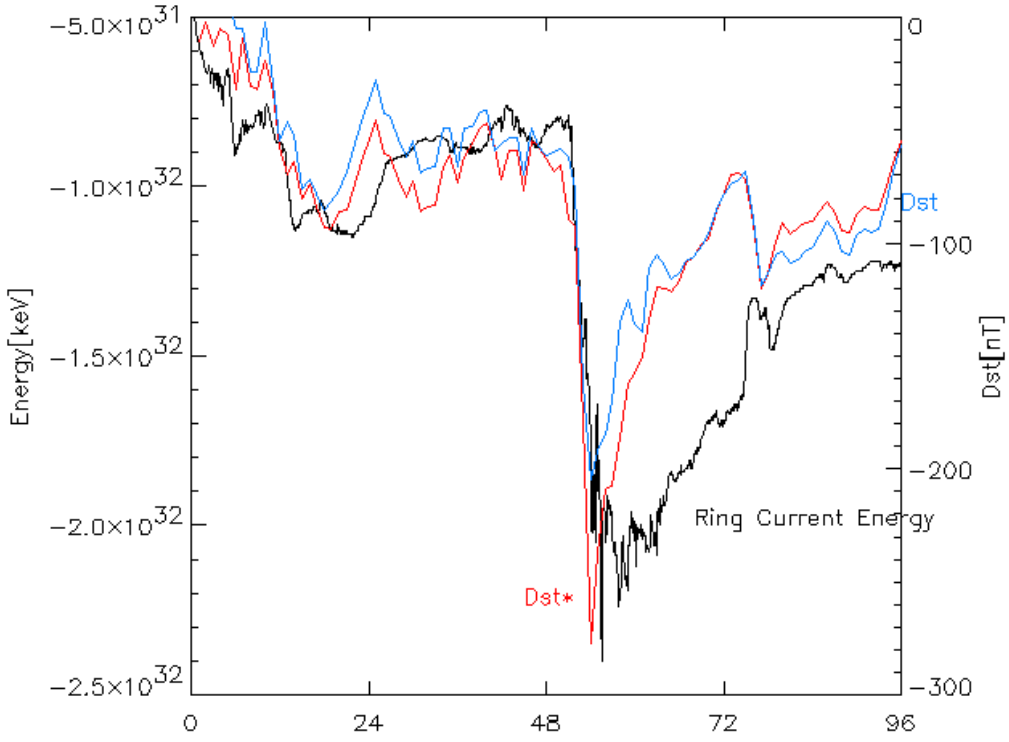

Figure 1. Energy and Dst plots for the ring current case without pitch angle diffusion. Dst is plotted in blue. Dst* is plotted in red. The negative ring current energy is plotted in black. In this case the ring current energy recovers significantly slower than the Dst index.

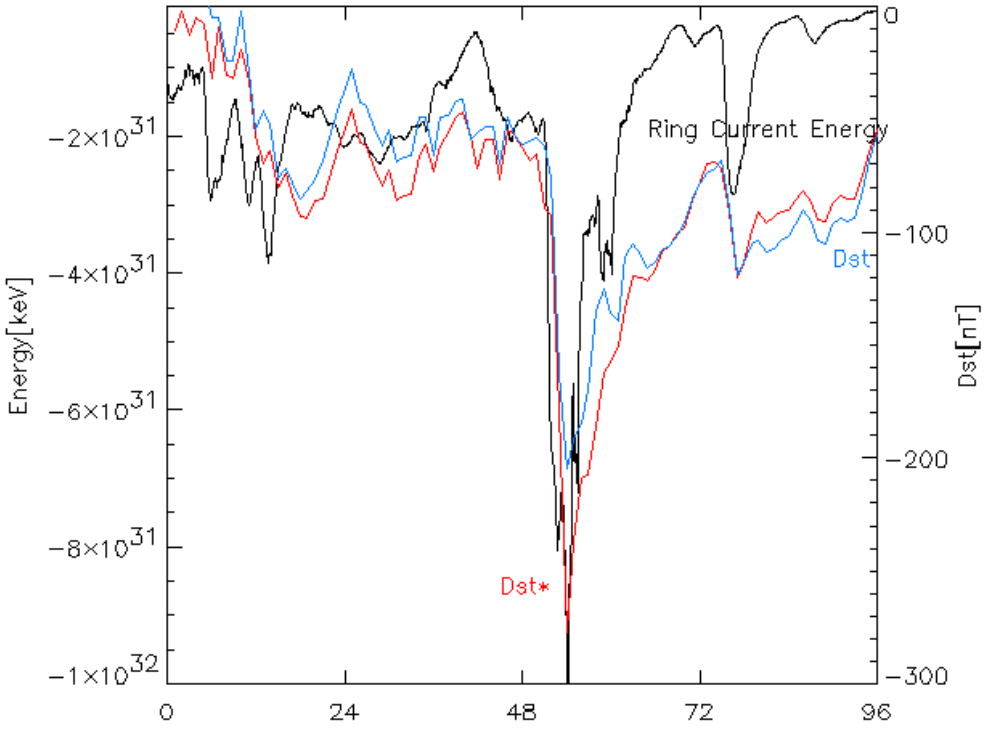

Figure 2. Energy and Dst plots for the ring current case with pitch angle diffusion. Dst is plotted in blue. Dst* is plotted in red. The negative ring current energy is plotted in black. In this case the ring current energy recovers faster than the Dst index.